The Effect of Orbit Inclination on the Exposure for the GLAST Sky Survey

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This study compares the exposures that GLAST would obtain in a low inclination orbit with that from the baseline 28.5° orbit, taking into account the effects of the South Atlantic Anomaly (SAA) and of occultation by the Earth. The basic conclusion is that for a one-year sky survey, the exposure is more uniform and 30% greater overall for 0° inclination rather than 28.5°. This result does depend on the variation of GLAST's effective area with inclination angle. The parameters of the 'Phony Gamma-ray Telescope,' an imaginary instrument that meets the specifications in the GLAST Science Requirements Document, were used here.

The orbit altitude and survey mode were assumed to be those for the baseline mission. GLAST was assumed to have a circular orbit with 550 km altitude. The baseline sky survey mode is zenith pointing with 'step rocking,' which means that the instrument axis is rocked alternately above and below the orbital plane on successive orbits to make the sky coverage more uniform. In this study, the slewing for the rocking motion was assumed to be instantaneous; several amplitudes, or rocking angles, were investigated. During SAA passages, no exposure was accumulated. The boundary of the SAA was assumed to be the same as currently used to determine when CGRO is turned off (Fig. 1).

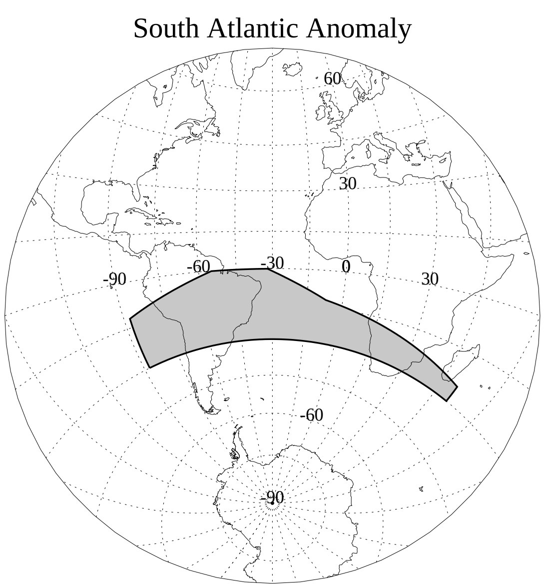

Figure 1. The extent of the South Atlantic Anomaly. No exposure is accumulated when GLAST is within the shaded region.

Exposures were calculated for a one-year sky survey. Because this is much longer than the ~54 day precession period of the orbit, the exposure was assumed to be uniform in right ascension and only the declination dependence was calculated. For none of the orbit inclinations considered is one year an integral multiple of the precession period, so the assumption of uniform exposure with right ascension actually is valid only at the few percent level.

Viewing directions with zenith angles greater than 100° were assumed to be occulted by the earth. The zenith angle of the horizon is greater, but 100° was chosen as an estimate of the cutoff required to avoid detecting earth albedo gamma rays. Even if the albedo emission would not swamp GLAST, directions contaminated with albedo emission are not useful for astronomy.

Three inclination angles were investigated: 28.5°, 0°, and 5°. The baseline for the GLAST mission is 28.5°. The 0° orbit represents the ideal case in terms of minimization of SAA passages, and 5° is a representative low, but not ideal, inclination.

For each inclination angle, exposures were calculated for six step rocking angles: 0°, 10°, 20°, 30°, 35°, and 40°. Profiles are shown in Figure 2 and the findings are summarized in Table 1. Please note that the exposures were calculated using the effective area profile of the 'Phony Gamma-ray Telescope' (PGT). The profile meets the specifications in the GLAST Science Requirements Document, but may be quite different from the actual profile of GLAST. The effective area for the PGT was assumed to be 8000 cm^2 on axis (for 1 GeV, say), and to vary with inclination angle θ as $(1 - (\theta/66°)^2)$, with zero effective area for $\theta > 66°$. *Different profiles will result in different exposures.*

For all of the inclinations considered, the most uniform exposure in Figure 2 is obtained with a 35° rocking angle. Greater rocking angles increase the exposure exposure lost to occultation by the earth (Table 1), but even for rocking angles as great as 40°, this is a small effect.

Of the three inclinations considered, the orbit with 28.5° inclination and 35° rocking angle has the least uniform exposure, owing to the observing time lost to the SAA below the equatorial plane. The overall average exposure is also least for this inclination. The average exposure for a 0° inclination orbit is 30% greater, with essentially all of the difference due to SAA passage at the higher inclination (Table 2). Even the 5° inclination orbit has 25% greater average exposure than the baseline orbit

A low inclination orbit has other potential advantages and at least one potential disadvantage. The advantages include reduced particle background and greater mass-to-orbit capability (for a correspondingly lower inclination launch). The disadvantage is that the exposure near the poles of the orbit is at fairly large inclination angles, typically 50° or more. If the point-spread function so far off axis degrades significantly, then the uniformly better exposure for a low-inclination orbit may not result in a uniformly greater sensitivity.

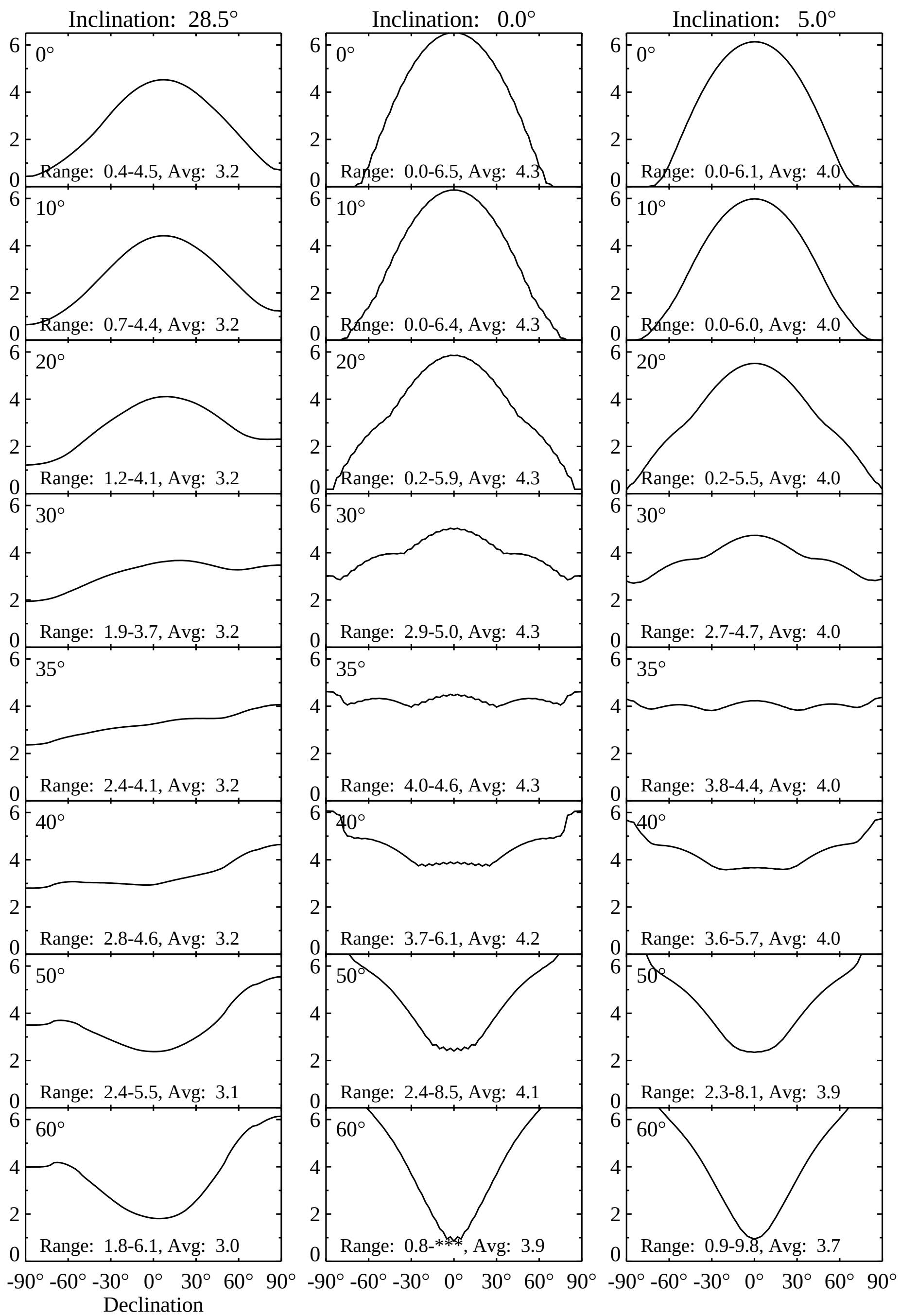

Figure 2. Profiles of exposure with declination for three orbit inclination angles and eight step rocking angles (indicated in upper left of each plot) in a one-year sky survey with GLAST. The effective area profile of the PGT is used for the exposure calculation (see text). The small-scale ripples in the 0° inclination profiles are artifacts from the calculation, for which a grid spacing of 2.5° in declination was used.

Inclination	Rocking Angle	Exposure (10^{10} cm^2 s) for 1-yr Sky Survey **Min.**	**Max.**	**Avg.**[1]	*Lost in SAA*	*Lost to Earth Occ.*
28.5°	0°	0.4	4.5	3.2	1.0	0.00
28.5°	10°	0.7	4.4	3.2	1.0	0.00
28.5°	20°	1.2	4.1	3.2	1.0	0.00
28.5°	30°	1.9	3.7	3.2	1.0	0.00
28.5°	35°	2.4	4.1	3.2	1.0	0.00
28.5°	40°	2.8	4.6	3.2	1.0	0.01
28.5°	50°	2.4	5.5	3.1	1.0	0.13
28.5°	60°	1.8	6.1	3.0	0.9	0.36
0.0°	0°	0.0	6.5	4.3	0.0	0.00
0.0°	10°	0.0	6.4	4.3	0.0	0.00
0.0°	20°	0.2	5.9	4.3	0.0	0.00
0.0°	30°	2.9	5.0	4.3	0.0	0.00
0.0°	35°	4.0	4.6	4.3	0.0	0.00
0.0°	40°	3.7	6.1	4.2	0.0	0.02
0.0°	50°	2.4	8.5	4.1	0.0	0.14
0.0°	60°	0.9	10.4	3.9	0.0	0.38
5.0°	0°	0.0	6.1	4.0	0.2	0.00
5.0°	10°	0.0	6.0	4.0	0.2	0.00
5.0°	20°	0.2	5.5	4.0	0.2	0.00
5.0°	30°	2.7	4.7	4.0	0.2	0.00
5.0°	35°	3.8	4.4	4.0	0.2	0.00
5.0°	50°	2.4	8.1	3.9	0.2	0.13
5.0°	60°	1.0	9.8	3.7	0.2	0.37
5.0°	40°	3.6	5.7	4.0	0.2	0.01

[1] Weighted by solid angle.

Table 1 -Sky Survey Exposures for Different Orbits and Rocking Angles

Inclination	Fraction of Time in SAA[1]
28.5°	23.6%
0°	0.0%
5°	5.6%

[1] For a one-year sky survey.

Table 2 -Observing Time Lost During SAA Passages